UPPER ORDOVICIAN RUGOSE CORALS OF CENTRAL NEW SOUTH WALES

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(Plates xxvi–xxx)

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Synopsis

Ten species of rugose corals are described and illustrated from the Upper Ordovician (Caradoc) limestones of central New South Wales. They include the new genera *Bowanophyllum* (type species *B. pilatum*) and *Rhabdelasma* (type species *R. exigua*), and four other new species, *Palaeophyllum jugatum, P. arrectum, Palaeophyllum? patulum* and *P.? laxum*. *Rhabdelasma* is one of the earliest rugosans to show rhabdacanths, occurring in an horizon of probably early Bolindian (late Caradoc) age. The New South Wales Ordovician fauna also exhibits representatives of *Helicelasma, Streptelasma?* and *Grewingkia*.

Introduction

Although the rugose corals are numerically subordinate to the tabulate corals in the Ordovician limestones of central New South Wales, they nevertheless constitute one of the more important groups for use in establishing biostratigraphic subdivision of the succession. Aspects of the stratigraphic distribution of the rugosoans have been previously outlined by Webby (1971, 1972, 1975). The distribution of the whole fauna is summarised in Text-fig. 1. *Hillophyllum* is the earliest form to appear, occurring in Fauna I of probable Gisbornian (early Caradoc) age. It is the earliest rugosoan to exhibit monacanthine septa. *Palaeophyllum* makes its appearance in Fauna II (early Eastonian), and is the first to show " laminar " septa. It becomes, by the late Eastonian (Fauna III), the most abundant and, at the species level, most diverse element of the New South Wales Ordovician rugosoan fauna. In Fauna III there is also the first appearance of solitary streptelasmatids (*Helicelasma* and *Streptelasma?*) and cerioid *Favistina*. Fauna IV (early Bolindian) is characterised by *Rhabdelasma*, the earliest form to exhibit rhabdacanths, *Bowanophyllum* and *Grewingkia*.

Stratigraphic Distribution

It now appears that there are two stratigraphically distinct Ordovician limestones in the region west of Parkes (Webby, in press). The lower is the Billabong Creek Limestone (Packham 1967 ; Sherwin 1970, 1973), which contains representatives of Fauna II, including the corals *Hillophyllum priscum*, *H.* sp., *Tetradium cribriforme*, heliolitids and the stromatoporoid *Ecclimadictyon*. It is succeeded by probable Eastonian graptolitic shales (Campbell and Durham 1970 ; Sherwin 1973) and by an unnamed limestone, presently included in the lower part of the Goonumbla Volcanics. The unnamed limestone crops out just north of Gunningbland and exhibits a rich coral fauna, including *Streptelasma?*

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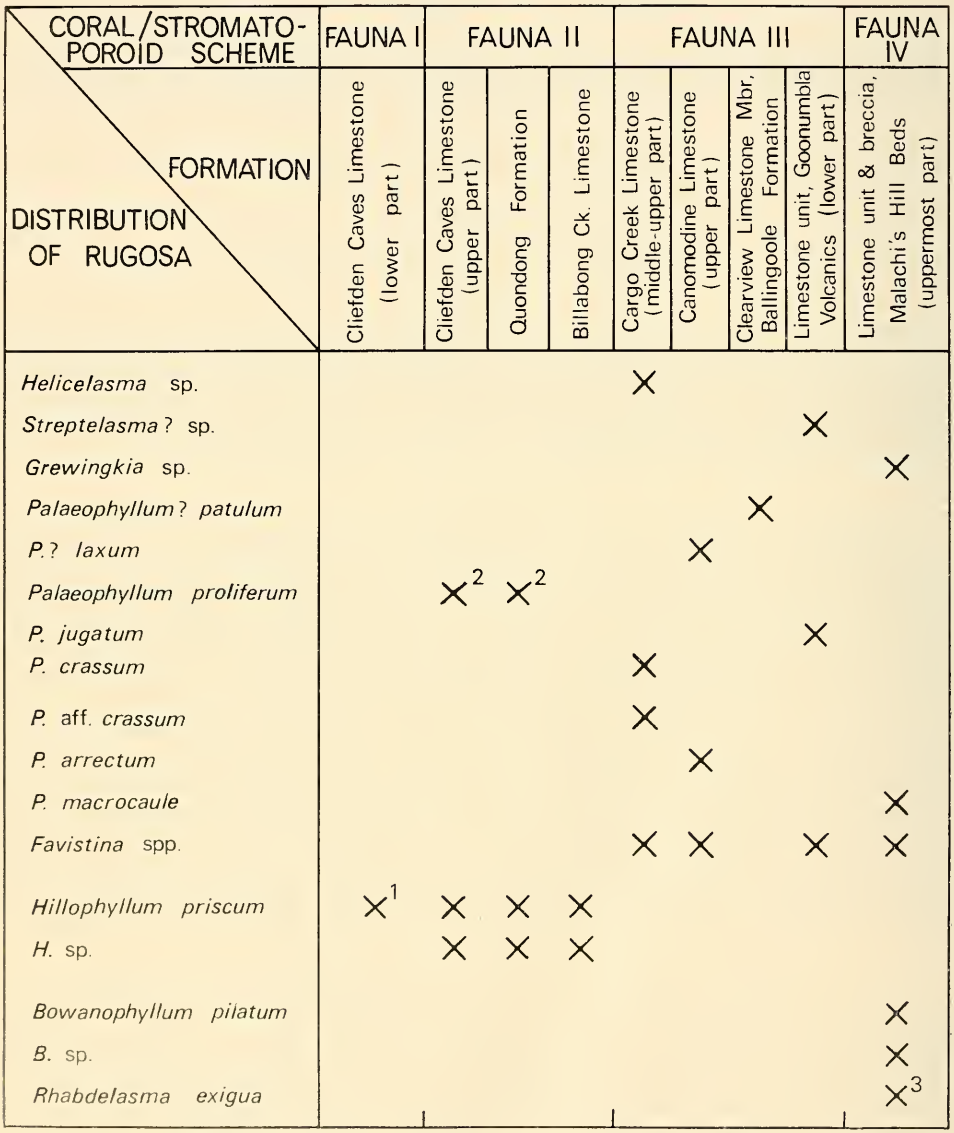
sp., *Palaeophyllum jugatum*, *Favistina* sp., *Plasmoporella inflata* and other heliolitids, and the stromatoporoid *Cliefdenella etheridgei*. It is considered to be a Fauna III assemblage of late Eastonian age.



Text-fig. 1. Diagram showing distribution of Late Ordovician (Caradoc) rugose corals in central New South Wales. Coral/stromatoporoid faunas I-IV of Webby (1969; 1972). First appearances of particular septal types are shown by numerals 1–3. 1. earliest form with monacanthine septa; 2. earliest species with " laminar " septa; 3. earliest with confirmed rhabdacanths.

The occurrence of *Cliefdenella etheridgei* was originally taken to be a diagnostic element of Fauna II (Webby, 1969). However, it has recently been found in a stratigraphically higher level (Fauna III) of the Cargo Creek Limestone (Stevens, 1950, 1957), and clearly has a more extended upward range. *Helicelasma* sp.

and *Palaeophyllum crassum* are associated with *Quepora calamus* and *Cliefdenella etheridgei* in beds of the Cargo Creek Limestone underlying the main fossiliferous units of the upper part of the succession. These latter contain *P.* cf. *crassum*, *Favistina* sp. and favositids. From equivalent horizons in the upper part of the Canomodine Limestone (Stevens, 1950 ; Ryall, 1965) on the south bank of the Belubula River, east of Cranky Rock, *Palaeophyllum? laxum*, *Favistina* sp. and *Halysites praecedens* have been found, and near Rockdale, *Palaeophyllum arrectum*, *Favistina* sp., and abundant favositids have been collected.

In the Clearview Limestone Member of the Ballingoole Formation (Bowan Park Group), *Palaeophyllum? patulum* is associated with a varied tabulate coral and stromatoporoid fauna (Semeniuk, 1973), also a Fauna III assemblage. *Favistina* is not recorded, but *Halysites praecedens* and *Palaeofavosites* make their first appearance in the Bowan Park succession, towards the top of the member. The Malachi's Hill Beds (Semeniuk, 1970) succeed the Bowan Park Group, and contain, in limestone breccia and a massive limestone unit at the top of the sequence, a rich and diverse coral fauna (Fauna IV). The limestone breccia has yielded *Grewingkia* sp., and the overlying limestone unit, *Palaeophyllum macrocaule*, *Favistina* sp., *Bowanophyllum pilatum*, *B.* sp., and *Rhabdelasma exigua*. Tabulate elements of the fauna include *Catenipora* sp., *Quepora* sp., *Palaeofavosites* spp., *Plasmoporella* sp., and *Heliolites* sp.

Systematic Descriptions

Genus HELICELASMA Neuman 1969

Type species. *H. simplex* Neuman 1969.

Discussion. The redefinition of the genus *Streptelasma* by Neuman (1969) has been discussed by McLean (1974*a*, p. 38). Included now in *Helicelasma* Neuman are many forms earlier thought congeneric with the type species of *Streptelasma*, *S. corniculum* Hall. Neuman regarded the following species as representative of *Helicelasma : Streptelasma fossulatum* Wang, 1948 ; *S. whittardi* Smith, 1930 ; *S. corniculum* Cox, 1937 ; *S. rusticum* (Billings, 1858) and *Helicelasma simplex* Neuman, 1969. The position of '*S.*' *rusticum* (Billings) is not certain. The transverse section figured by Lambe (1901, Pl. VII, fig. 3) shows a wide axial structure of intertwined septal lobes and lamellae, a characteristic feature of the genus *Grewingkia* Dybowski, 1873. However the species, as illustrated by Cox (1937, Pl. II, figs 11–13) shows a weak axial structure and all features characteristic of *Helicelasma*. Unfortunately the types are lost (Cox, 1937, p. 12) but the thorough study of widespread material of the species made by Cox would appear to give a good basis for interpreting the form as a representative of *Helicelasma*. The species has been recorded from numerous localities of Richmond age in North America (see Bassler, 1950), but thin-section analysis is required for verification. *Streptelasma poulseni* Cox, 1937 from the Cape Calhoun Formation of north-western Greenland (Richmond) would also appear to be a representative of *Helicelasma*. As mentioned by McLean (1974*a*), *Streptelasma ruttneri* Saleh *in* Flügel and Saleh, 1970 from the Llandovery of north-east Iran shows typical characteristics of *Helicelasma* and is included here in that genus.

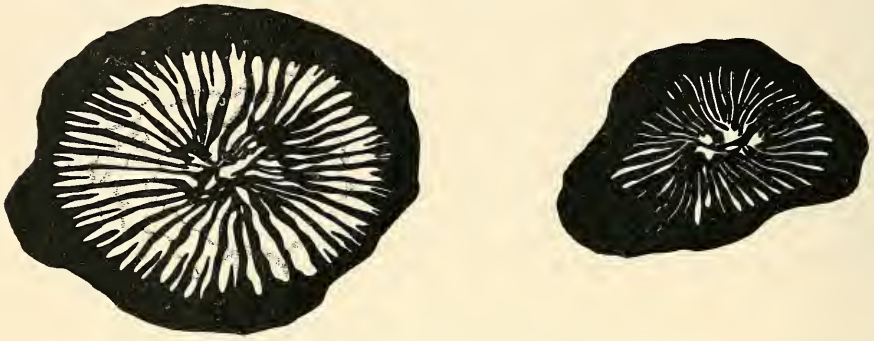
Helicelasma sp.

Pl. XXVI, figs 6–8 ; Text-fig. 2

Material. SUP 75160–75162 from middle-upper part of the Cargo Creek Limestone ; tributary south-east of Canomodine Creek.

Description. Corallum solitary, of indeterminate growth form owing to incompleteness of material ; only late neanic and ephebic growth stages preserved. Corallum up to 25 mm in diameter, with calice deep, at least 10 mm depth. Septa are strongly dilated in peripheral stereozone in ephebic stage, this zone being

0·15–0·2 of radius of corallite. Major septa have a maximum number of 41 in largest, most complete specimen (Pl. XXVI, fig. 6); gradually tapering towards axis in ephebic stage, with a few dilated lobes and traces of free lamellae in axial zone. Minor septa are short and of variable length; extending inwards generally only to about 0·3 of corallite radius. In late neanic stage, septa are strongly dilated being almost in lateral contact; major septa extend to axis. Owing to the fragmentary material, only a few tabulae were observed in section; they are strongly arched, apparently mainly complete, with a broad, central flattened region; spacing is approximately 0·8–1·2 mm apart.



Text-fig. 2. *Helicelasma* sp., transverse sections, ×2·5. SUP 75160b, ephebic stage (left); SUP 75161, neanic stage (right).

Remarks. The above described form bears close resemblances to "*Streptelasma corniculum*" of Cox (1937) and Lambe (1901) characteristic of the Trenton of North America. Following the revision of Hall's material by Neuman (1969) it is evident their material is not conspecific with that of Hall (1847) and is representative of *Helicelasma*. The material of Cox (1937, Pl. 1, fig. 2*b*) from strata of Trenton age in Cornwall, Ontario appears to have a more strongly developed ephebic axial structure than that of the N.S.W. specimens. However the ephebic section of Lambe (1901, Pl. VI, fig. 7*b*) from the Trenton of Ottawa, Ontario has a very weak axial structure more comparable to that of the N.S.W. form. The North American species would thus appear to be quite variable and the material from the Cargo Creek Limestone may be conspecific with it. More complete specimens from Cargo Creek are required, however, before definite synonymy can be established. A new specific name for the North American form must also be selected.

Genus STREPTELASMA Hall, 1847

Type species. *S. corniculum* Hall, 1847.

Streptelasma? sp.
Pl. XXVI, figs 1–5

Material. SUP 75195, 77267, from unnamed limestone in lower part of Goonumbla Volcanics; "Currajong Park", just north of Gunningbland.

Description. Corallum solitary, straight, subcylindrical. Specimen SUP 75195 is incomplete but a height of at least 70 mm is represented, with diameter reaching 28 mm. Calice straight-sided with depth of approximately 16 mm. A wide peripheral stereozone is present throughout visible ontogeny, although early growth stages are lacking; it reaches a width of approximately 0·3 of corallite radius at base of calice. In ephebic stage major septa are thin, tapering, withdrawn from axis, extending approximately 0·7–0·8 of corallite radius. Septal lamellae occur in the axial region but no axial structure is developed. Septal

number cannot be determined owing to incompleteness of material, but is estimated to be approximately 56 major septa at base of calice. Minor septa are short, barely protruding beyond peripheral stereozone. In the late neanic stage (Pl. XXVI, fig. 3), major septa are only weakly dilated and extend to corallite axis where they may be slightly twisted. Tabulae are incomplete, forming strongly arched series with flattened central zone. Average spacing is 2 mm towards the periphery, whereas it is only 0·3–1·0 mm axially.

Remarks. Since these specimens are incomplete, generic determination is uncertain. They seem most likely to be representatives of *Streptelasma* because the septa do not appear to have become greatly dilated in early growth stages, and the major septa of the ephebic stage are somewhat withdrawn from the axis with rather irregular axial ends.

Genus GREWINGKIA Dybowski, 1873

Type species. *Clisiophyllum buceros* Eichwald, 1856.

Grewingkia sp.
Pl. XXVI, figs 9–12

Material. SUP 75223 from the limestone breccia underlying the limestone lens in the uppermost part of the Malachi's Hill Beds ; northeast of Malachi's Hill.

Description. Corallum small, solitary, growing in association with tabulate coral *Catenipora*. Attains maximum diameter of 5·4 mm. Broad peripheral stereozone composed of dilated septa to a width of approximately 1 mm. Major septa taper markedly inside peripheral stereozone ; extend unbroken up to 0·6 of corallite radius and frequently show lateral " tubercles " and axial lobes (Pl. XXVI, fig. 9). Minor septa may project slightly beyond stereozone. Axial region of corallite occupied by dense structure (approximately 2 mm in diameter) of anastomosing septal lobes and lamellae. Earlier growth levels show axial structure to be rather smaller and slightly more open. Nature of tabulae unknown.

Remarks. The species is distinguished from all previously described species of *Grewingkia* in exhibiting at the ephebic stage dilated septa and an axial structure with strongly dilated septal lobes and lamellae. It may be related to *Densigrewingkia* (type species, *D. pyrgoidea* Neuman 1969) but differs in lacking strong sclerenchymal thickening of the axial structure. *Grewingkia* is represented by two species in the late Lower or early Middle Llandovery of central New South Wales (McLean, 1974*a*), but this is the first record of the genus in the Ordovician of Australia. Another smaller Ordovician species of *Grewingkia* (SUP78210) with much less dilated septa has recently been found by I. Percival (pers. comm.) ; it is associated with *Halysites* sp. in a limestone lens of the Angullong Tuff (locality CO.1/50 of Smith, 1966).

Genus *Palaeophyllum* Billings, 1858

Type species. *P. rugosum* Billings 1858.

Discussion. For synonymy and previous discussion of this genus, see Webby (1972) and McLean (1975). The species *P. jugatum*, *P.* aff. *crassum* and *P. arrectum* are regarded as typical representatives of *Palaeophyllum*, but *P.? patulum* and *P.? laxum* because of their " pseudo-colonial " habit are only tentatively assigned to the genus.

Palaeophyllum jugatum sp. nov.
Pl. XXVII, figs 1–7 ; Text-fig. 3A–B

Material. Holotype SUP 74258 ; paratypes SUP 43261–43262, 75150–75157, 74259–74269. Unnamed limestone in lower part of the Goonumbla Volcanics ; " Currajong Park ", just north of Gunningbland.

Description. Corallum is phaceloid (less commonly dendroid). Increase is axial and parricidal, with up to four (or five?) offsets from one calice. Corallite diameter ranges from 3·5 to 4·5 mm in mature specimens. Calice relatively deep (up to 3·5 mm), steep-sided, with pronounced axial boss often present. Peripheral stereozone ranges from 0·2–0·5 mm in width. Septa of two orders ; major septa are moderately dilated, tapering only slightly from stereozone towards axis ; range in number from 19 to 22. Individual corallites of a single corallum may exhibit major septa of markedly differing lengths ; in some they extend inwards to form a solid axial structure up to 1 mm wide, in others only one or two septa elongate to form an axial element (usually blade-like), and still others may not reach the axis. Owing to the indifferent preservation of specimens, it proves difficult to elucidate nature of the much thickened axial structure. However, in one slightly better preserved specimen (SUP 75151), the axial structure seems to be formed of fused to partially fused septal lobes. Minor septa, where discernible, are short and barely protrude inwards beyond the peripheral stereozone. Tabulae are usually complete, moderately to strongly updomed ; they have a spacing of up to 12 in 5 mm.

Remarks. This species differs from *P. proliferum* " in having more widely spaced corallites and much less prominent budding " (Webby, 1972, p. 153), and also by exhibiting, in many corallites, the development of a solid axial structure. The only other New South Wales species to show conspicuous coalescence of inner ends of septa to form an axial structure is *P. macrocaule*, Webby, 1972. However, it has larger corallite dimensions, more conspicuous minor septa, and shows a different mode of budding. An axial structure has also been described in *P. aggregatum* Nicholson and Etheridge 1878 from the Craighead Limestone of Girvan, Scotland (Nicholson and Etheridge, 1878, p. 71 ; Wang, 1948, p. 101), but it tends to be a more loosely formed structure than in *P. jugatum*. *Palaeophyllum aggregatum* exhibits few other resemblances to *P. jugatum*. Thin sections of *P. aggregatum* in Sydney University palaeontological collections (SUP 77268–69, 78150) show it to have larger corallite dimensions, much more dilated septa peripherally, a marked denticulation on inner edges of the septa, and much longer minor septa.

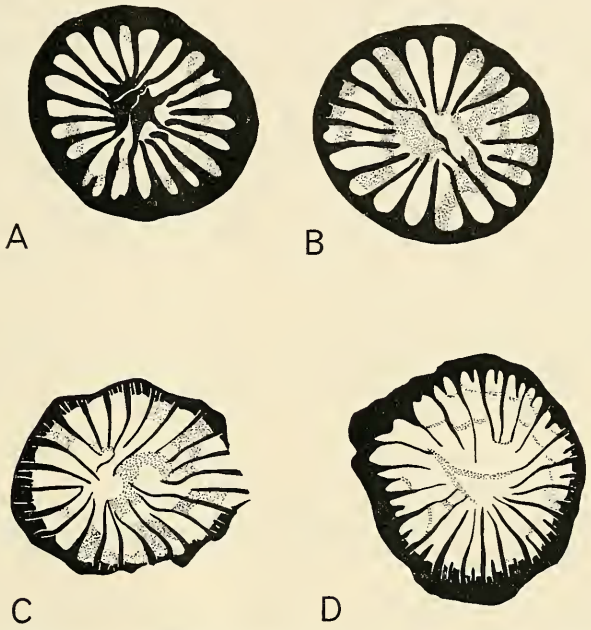
Two species from the Late Ordovician of the Altai Mountains show some development of an axial structure. In *P. lebediensis* (Čherepnina, 1960) this structure is rather weak and formed by fusion of axial ends of a few septa, without significant dilation (Čherepnina, 1960, Pl. o–x, figs 4, 5 ; Ivanovskiy, 1969, Pl. x, fig. 1). *Palaeophyllum virgulta* (Čherepnina, 1960) may show a tendency to form a more pronounced axial structure (Čherepnina, 1960, Pl. o–xi, fig. 2b) but differs from *P. jugatum* in having a more open axial structure, greater corallite diameter and lateral rather than axial increase.

Palaeophyllum aff. *crassum* Webby 1972
Pl. xxvi, fig. 13 ; Text-fig. 3d

Material. SUP 75159, from the upper part of the Cargo Creek Limestone (associated in an horizon with *Favistina*) ; tributary on the south-east side of Canomodine Creek.

Comparative description. Corallum is phaceloid, in part fragmented by post-burial alteration (mainly pressure solution). Corallite diameter ranges from 7–9 mm. Septal number varies from 44 to 48 in mature corallites. Major septa are somewhat withdrawn from the axis ; weakly dilated in the 0·4–0·5 mm wide peripheral stereozone, tapering rapidly inside stereozone, and more gradually towards axial ends. Minor septa are short, extending up to twice width of stereozone. Tabulae are complete, generally strongly arched periaxially and deeply sagging axially, but occasionally exhibiting flatter, less updomed or sagging forms. Peripheral spacing of tabulae ranges from 4–7 in 5 mm.

This form has been collected from the Cargo Creek Limestone in the same tributary of Canomodine Creek as *P. crassum* Webby 1972, but from a slightly higher horizon. It compares closely with *P. crassum* differing only in having a slightly smaller corallite size, and more widely spaced tabulae, with more pronounced axial sag and periaxial updoming. It may eventually prove to be conspecific with *P. crassum* when more specimens are found to enable the range of variability of the species to be more fully assessed.



Text-fig. 3. A–B. *Palaeophyllum jugatum* sp. nov., SUP 74258a, holotype, ×8.
C. *Palaeophyllum arrectum* sp. nov., SUP 75158c, holotype, ×4.
D. *Palaeophyllum* aff. *crassum* Webby 1972, SUP 75159a, ×4.

Palaeophyllum arrectum sp. nov.

Pl. XXVII, figs 8–9 ; Pl. XXVIII, figs 1–2 ; Text fig. 3C

Material. Holotype SUP 75158, from the upper part of the Canomodine Limestone, near " Rockdale ".

Description. Corallum phaceloid ; also damaged by pressure solution. Corallite diameter ranges from 6·0–7·5 mm. Major septa are slender, tapering slightly from peripheral stereozone towards axis ; mostly reaching to about 0·7 of corallite radius ; vary in number from 20 to 24. Minor septa are generally only very rarely visible, and then virtually confined to narrow (0·4 mm average width) peripheral stereozone. Tabulae are complete or rarely incomplete, slightly to moderately arched, occasionally with a broad, flattened axial region, or a weak axial depression. Spacing of tabulae ranges from 6–8 in 5 mm.

Remarks. Of the New South Wales Ordovician forms, only *P. crassum* and *P.* cf. *crassum* closely resemble this species. However, they both differ in exhibiting more pronounced axial sag of the tabulae, and more clearly recognisable minor septa.

Palaeophyllum? patulum sp. nov.

Pl. XXVIII, figs 3–7

Material. Holotype SUP 75194 ; paratypes SUP 29131, 75182–75190. Clearview Limestone Member of the Ballingoole Formation (Bowan Park Group) at Malachi's Hill.

Description. Corallum is solitary-dendroid ; the many single individuals probably include both original solitary coralla and fragments broken off dendroid colonies. Mode of budding unknown. Corallites are subcylindrical ; some surrounded by encrusting clathrodictyid stromatoporoid ; with diameter ranging from 10 to 14 mm. Narrow peripheral stereozone varies from 0·4–0·8 mm in width ; composed mainly of lamellar sclerenchyme with septa only slightly dilated. Septa range in number from 52 to 64 in mature corallites. Major septa generally rather slender, tapering slightly towards axis, and extending up to approximately 0·7 of corallite radius. In earlier growth stages, major septa may extend to axis (though an axial structure is not developed), or they may be slightly withdrawn ; but in later stages may be still more strongly withdrawn. Minor septa of variable length, usually short, but may reach inwards up to twice the width of the stereozone. Tabulae are complete and incomplete ; steeply inclined upward adjacent to stereozone, with broad flat to gently sagging axial region. Spacing of tabulae from 4–6 in 5 mm.

Remarks. This species is only tentatively assigned to *Palaeophyllum* because it does not show the typical fasciculate growth habit of the genus. It has been referred to previously by Semeniuk (1970, p. 21 ; 1973, p. 84) as a " *Streptelasma* ". Webby (1972, p. 154) has noted already the differences between this species and *P. crassum*.

Palaeophyllum? laxum sp. nov.

Pl. XXVIII, figs 8–10 ; Pl. XXIX, figs 1–3

Material. Holotype SUP 75163 ; paratypes 43264, 75164–75175, 75177–75180. Upper part of the Canomodine Limestone, south bank of Belubula River, east of " Cranky Rock ".

Description. Corallum fasciculate to possibly solitary ; poorly preserved with recrystallisation and some distortion of specimens. Lateral, non-parricidal increase exhibited by holotype. Corallites sub-cylindrical, with diameter ranging up to 13 mm. Peripheral stereozone ranges from 0·8 to 1·5 mm in width, composed of dilated septa, but little or no differentiation of lamellar sclerenchyme. Septa vary in number from 62 to 66 in mature corallites, strongly dilated in stereozone but tapering rapidly towards axis. Major septa usually extent inward to approximately 0·6–0·7 of corallite radius, but in some specimens (Pl. XXIX, fig. 2) they reach the axis, forming a very loose aggregation of septal ends ; no apparent septal lobes. Recrystallized calcite infilled areas in the centres of some corallites (Pl. XXVIII, fig. 8 ; Pl. XXIX, fig. 1) do not represent solid axial structures. Minor septa are long, usually 0·4–0·5 of corallite radius. Tabulae are mainly incomplete or partly coalescing ; very steeply inclined peripherally, with highly arched periaxial ridge and deep axial depression. Spacing of tabulae is highly variable, from 0·5 to 2·5 mm apart.

Remarks. Although only one corallum exhibits definite offsets, the general abundance and association of specimens in the one sampled horizon east of " Cranky Creek " suggest that they belong to a colonial rather than a solitary species.

Both *P.? laxum* and *P.? patulum* have a similar solitary-fasciculate habit, but in other respects are markedly different. *P.? laxum* has more dilated septa in the peripheral stereozone, longer minor septa, and the tabulae more steeply inclined peripherally with more prominent downflexing in the axial region.

Genus BOWANOPHYLLUM gen. nov.

Type species. *Bowanophyllum pilatum* sp. nov.

Diagnosis. Corallum solitary, usually ceratoid ; calice very deep, funnel-shaped. Interior of corallum, even axially, almost entirely filled by dense tissue of long, rod-like trabeculae of uncertain original microstructure set in lamellar sclerenchyme. Septa not clearly differentiated into major and minor. Tabulae limited to one or two complete, flat to gently sagging elements just beneath calice and at points of rejuvenescence. No dissepiments.

Discussion. This new genus appears very closely similar to *Rhabdocyclus* Lang and Smith 1939 (*pro Acanthocyclus* Dybowski 1873), a mainly Silurian form. *Rhabdocyclus* is characterised by having a patellate-trochoid form, two orders of dimorphacanthine septa and usually lacks tabulae. However, a few tabulae have been recorded in one specimen of the type species, *R. fletcheri* (Edwards and Haime), by Hill (1936, p. 202) and from specimens of *R.* aff. *transiens* Hill (1936, p. 204). By comparison, *Bowanophyllum* is typically a ceratoid form, the septal spines are much longer and more closely packed, apparently only of the holacanthine type, and lacking differentiation into major and minor presumably because of extreme length of the minor ; the tabulae are restricted to one or two at points of rejuvenescence and at the base of the calice, possibly related to pauses in growth of the corallum. This latter feature is also seen in *Tryplasma primum* Hill 1936, a transitional member of the *Rhabdocyclus–Tryplasma* lineage of the British Wenlock Shales (Hill, 1936, p. 199, fig. 23, Pl. 30, figs 43–44), and a species Ivanovskiy (1969, p. 48) regards as representative of *Rhabdocyclus*. *Bowanophyllum* is distinguished from this species on the basis of having more closely spaced coarser trabeculae forming septa seemingly of one order only.

The only recorded Ordovician species of *Rhabdocyclus* are the Estonian *R. aequispinatus* Reiman, 1958 from the Vormsi horizon (late Upper Caradoc) and *R. atavus* Kaljo, 1958 from the Rakvere horizon (early Upper Caradoc). These two species, regarded as synonymous by Ivanovskiy (1969, p. 50), are clearly distinguishable from *Bowanophyllum*. They have a trochoid growth form and short septal spines, the densely occupied area of septal spines and lamellar sclerenchyme is confined to lower and outer parts of the corallum, and they lack tabulae.

Also showing similarities to *Bowanophyllum* is the Ordovician genus *Coelostylis* Lindström 1880, as interpreted by Neuman (1967). The latter has closely spaced, long septal spines as exhibited by *Bowanophyllum*, but they are monacanthine and lack wrapping of lamellar sclerenchyme. *Coelostylis* also differs in possessing a marked axial structure and calical boss of partially fused septal spines, and in lacking tabulae. However the dense structure of septal spines apparent in transverse sections of *Coelostylis compactum* (Hill, 1953, Pl. 1, figs 4a–b) from the Middle Caradoc Sphaeronite Limestone of Norway is very closely comparable to that shown by *Bowanophyllum*. Weyer (1973) interpreted *Coelostylis* as having septal pores, although they are not apparent in the type species figured by Neuman (1967). There is no evidence of septal pores in *Bowanophyllum*, all intertrabecular loculi being filled with lamellar sclerenchyme.

Bowanophyllum pilatum sp. nov.

Pl. XXIX, figs 4–11 ; Pl. XXX, fig. 1

Material. Holotype SUP 75197, paratypes SUP 75196, 75198–75207 ; from limestone unit in the uppermost part of Malachi's Hill Beds, north-east of Malachi's Hill.

Description. Corallum solitary, usually ceratoid, frequently showing rejuvenescence (Pl. XXIX, figs 6–7). Corallite diameter ranges to common maximum of 15–17 mm, with corallite height unknown, but estimated to be at

least 50 mm. Calice is very deep and inverted funnel-shaped. Septa are formed of series of long, close spaced trabeculae of indeterminate original microstructure, extending inwards to axis and wrapped in lamellar sclerenchyme ; lack of differentiation between major and minor septa presumably due to extreme length of minor ; virtually the entire lumen, even axially, is filled with a dense tissue composed of acanthine septa and associated lamellar sclerenchyme ; typically the septa are not in contact, and the lamellar sclerenchyme fills the spaces between them. The predominant continuity of layering of the lamellar sclerenchyme between adjacent septa and around discrete trabeculae of a single septum suggests it represents real growth lamellae, rather than a diagenetically-formed microstructure. The few observed discontinuities in the layering of the lamellar sclerenchyme and the very rare occurrences of sutures between individual septa may best be interpreted as the result of pressure solution selectively disrupting or exsolving portions of the original lamellar sclerenchyme. The case for inferring the layering as secondary pseudo-lamellar tissue (Oekentorp, 1974) is unconvincing. Trabeculae have common diameter of 0·25–0·35 mm, and usually gently inclined (20–30°) upwards in outer parts of corallum, steepening to almost vertical near axis. Whether the presently structureless trabeculae originated by replacement from rhabdacanths is uncertain, but there is no trace of rhabdacanthine septa in corallum. Septal number is difficult to determine in transverse sections, but there is up to 86 in mature corallites. Horizontal skeletal elements are rarely evident, except at points of rejuvenescence and at the base of the calice. At these levels, one or two wide spaced, flat or slightly sagging tabulae may occur (Pl. xxx, fig. 5).

Remarks. A number of specimens (Pl. xxx, figs 2–4) from the same horizon and locality as the type species seem likely to represent a smaller species of *Bowanophyllum*, although the possibility that they comprise early growth stages of *B. pilatum* cannot be entirely ruled out. They are solitary, ceratoid, up to 7·0 mm in diameter, and exhibit an occasional rejuvenescence. Septa are acanthine. Only at a rejuvenescence (Pl. xxx, fig. 2) are septa shown to be weakly differentiated into major and minor, but some of the ' minor ' septa seem to be as prominent as the major in extending towards the axis. Up to 24 ' major ' septa occur. Very broad, dense peripheral stereozone occupies almost two-thirds of the corallite diameter. Area of tabularium almost entirely filled with axial ends of acanthine septa. Only a very rare occurrence of flat to sagging complete tabulae (Pl. xxx, fig. 4).

Genus RHABDELASMA gen. nov.

Type species. Rhabdelasma exigua sp. nov.

Diagnosis. Corallum small, solitary (usually ceratoid) and possibly dendroid ; with rhabdacanthine septa and broad peripheral stereozone. Septa of two orders ; both break down into discrete spines, the major near the axis and the minor just inside the peripheral stereozone. Tabulae are mainly incomplete, markedly sagging in the outer part of the tabularium, and gently updomed axially. No dissepiments.

Discussion. The majority of Ordovician rugosoans with acanthine septa that have been studied in terms of their septal microstructure have been shown to have monacanthine trabeculae (Neuman, 1967 ; Webby, 1971 ; Weyer, 1973). The only forms for which rhabdacanthine trabeculae have been confirmed are *Tryplasma antiqua* Reiman, 1958 and *Rhabdocyclus acquispinatus* Reiman 1958 (regarded as having dimorphacanths by Ivanovskiy, 1969), both from the Vormsi horizon (late Caradoc) of Estonia. *Tryplasma antiqua* differs from *Rhabdelasma* in having shorter septa and a narrower stereozone (Reiman, 1958, Pl. II, figs 9–10). *Rhabdelasma acquispinatus* has even shorter septa, and lacks tabulae (Reiman,

1958, Pl. II, figs 12–13). *Rhabdocyclus atavus* Kaljo 1958, considered synonymous with *R. aequispinatus* by Ivanovskiy (1969), comes from a lower stratigraphical level—from the Rakvere horizon (early Upper Caradoc) of Estonia—but its septal microstructure has not been described. If in fact *R. atavus* eventually proves to exhibit rhabdacanths, it will be the earliest form to show this microstructure. *Rhabdelasma*, in coming from an horizon of approximately Upper Caradoc age (see earlier discussion), certainly no older than that containing *Rhabdocyclus atavus* and no younger than that with *T. antiqua* and *R. aequispinatus*, represents one of the earliest forms to exhibit rhabdacanths.

Weyer (1973) described several new genera including *Lambelasma* (probably a junior synonym of *Lambeophyllum* Okulitch, 1938) and *Coelolasma*, and substantially reinterpreted *Coelostylis* Lindström 1880. He based these descriptions on material collected from Pleistocene glacial erratics in North Germany and Poland, supposedly derived from the Baltoscandian Macrourus Limestone of Middle Caradoc age. These forms are characterised by monacanthine trabeculae, although in high levels of the calice, Weyer considers rhabdacanths to be developed. This latter observation, however, is based on the shape of inner edges of the septa, rather than on the internal structure of the trabeculae; hence the presence of rhabdacanths is not proven. Weyer also regarded the presence of septal pores as diagnostic of these forms. *Rhabdelasma exigua* exhibits some discontinuities in individual septa, as seen in transverse section. These may reflect septal pores especially as the breaks often occur between groups of trabeculae, rather than between individual trabeculae, as in cystiphyllids, e.g., *Holmophyllum* Wedekind 1927 (McLean, 1974*b*). However, no definite septal pores could be confirmed in longitudinal sections. *Rhabdelasma* should be assigned to the family Tryplasmatidae (Etheridge, 1907) rather than to Weyer's (1973) Lambelasmatidae.

Rhabdelasma shows some similarities to the genus *Neotryplasma* Kaljo, 1957. However the type species of the latter, *N. longiseptata* Kaljo, 1957 (Vormsi Horizon, Estonia: Late Caradoc) lacks the broad peripheral stereozone of *Rhabdelasma* and there is some development of a loose axial structure of grouped septal spines (Kaljo, 1957, Pl. XVI, figs 9–12; Shurygina, 1973, Pl. XXVIII, figs 1–3). *Neotryplasma codonophylloides* Kaljo, 1957 (Porkuni Horizon, Estonia: Upper Ashgill) apparently has greater development of a peripheral stereozone and may be more closely related to *Rhabdelasma*. Unfortunately there is no record of the nature of the septal microstructure in any described specimens of *Neotryplasma*. Shurygina (1973) has also recorded *Neotryplasma* from the Cherdinsk, Typylsk and Rassokhinsk Horizons of the central and northern Urals (Middle-Upper Caradoc).

Rhabdelasma exigua sp. nov.

Pl. XXX, figs 5–11

Material. Holotype SUP 75212, paratypes SUP 75213–75220, 75222; from limestone unit at the top of Malachi's Hill Beds, north-east of Malachi's Hill.

Description. Corallum usually solitary, but possible lateral budding (with corallites growing together in a cluster) is shown by more than one specimen (Pl. XXX, figs 5 and 8). Growth form is ceratoid, with maximum diameter of 5–7 mm. Peripheral stereozone broad at all growth stages, from 0·4–0·6 of corallite radius, composed of dilated septa and set in a tissue composed either of true primary lamellar sclerenchyme or, possibly, of secondary pseudolamellar material. It is difficult to resolve the nature of the microstructure in the peripheral stereozone owing to poor preservation. However, it is apparent that the septa, rather than being closely linked along sutures, are separated by spaces filled with lamellar tissue. Septa are of two orders, ranging from a total of 32 to 40 in

mature corallites; each is composed of a single row of rhabdacanthine trabeculae. Rhabdacanths consist of discrete dark bundles of radiating fibres set in lamellar tissue (Pl. xxx, fig. 11). Minor septa are largely confined to peripheral stereozone; where they protrude inside the border, form discrete spines. Major septa extend to axis or may be slightly withdrawn; towards axial ends become discrete spines but no axial structure present. Occasional disruptions in the plane of the septum between groups of trabeculae, as seen in transverse section (Pl. xxx, figs 7 and 10), may represent septal pores, but have not been confirmed in available longitudinal sections. Throughout ontogeny, septa usually well separated, but in an early stage of one specimen (SUP 75213) septa are closely spaced together. Tabularium sharply differentiated from peripheral stereozone; tabulae usually seen to be incomplete; strongly sagging peripherally, and gently arched in axial region, although disrupted by trabeculae (Pl. xxx, fig. 9). Spacing of tabulae is extremely variable; 0·6–1·5 mm apart in available material. No dissepiments seen.

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EXPLANATION OF PLATES

Plate xxvi

Figs 1–5. *Streptelasma*? sp., unnamed limestone north of Gunningbland, ×2·5. 1. SUP 75195a, transverse section, late ephebic stage. 2. SUP 75195d, transverse section, ephebic stage. 3. SUP 75195f, transverse section, neanic stage. 4. SUP 75195h, longitudinal section. 5. SUP 77267, transverse section.

Figs 6–8. *Helicelasma* sp., middle-upper part of Cargo Creek Limestone, south-east tributary of Canomodine Creek, ×2·5. 6. SUP 75160a, transverse section, ephebic stage. 7. SUP 75160c transverse section, early ephebic stage. 8. SUP 75162c, longitudinal section.

Figs 9–12. *Grewingkia* sp., limestone breccia, uppermost part of Malachi's Hill Beds, north-east of Malachi's Hill ; specimen associated with *Catenipora* sp. ; transverse sections, ×5. 9. SUP 75223a. 10. SUP 75223b. 11. SUP 75223c. 12. SUP 75223d.

Fig. 13. *Palaeophyllum* aff. *crassum* Webby 1972, upper part of Cargo Creek Limestone, south-east tributary of Canomodine Creek, transverse and longitudinal sections, ×3. SUP 75159b.

Plate xxvii

Figs 1–7. *Palaeophyllum jugatum* sp. nov., unnamed limestone north of Gunningbland. 1–2. holotype. 1. SUP 74258a, ×3, showing quadripartite division. Note two corallites (one with solid axial structure) towards bottom margin of figure are those depicted in Text-fig. 2A–B. 2. SUP 74258b, ×4, longitudinal section exhibiting calice. 3. SUP 43261, paratype, ×3. 4. SUP 74262b, paratype, ×3, transverse section showing axial, parricidal division of one corallite which also exhibits prominent minor septa. 5. SUP 74262a, paratype, ×4, transverse section exhibiting four or five? buds. 6. SUP 75152a, paratype, ×4, longitudinal section showing axial, parricidal increase. 7. SUP 74259b, paratype, ×4, longitudinal section.

Figs 8–9. *Palaeophyllum arrectum* sp. nov., upper part of Canomodine Limestone near " Rockdale ", holotype, ×3. 8. SUP 75158a, transverse section. 9. SUP 75158e, longitudinal section.

Plate xxviii

Figs 1–2. *Palaeophyllum arrectum* sp. nov., upper part of Canomodine Limestone near " Rockdale ", holotype, ×3. 1. SUP 75158k, transverse section. 2. SUP 75158n, longitudinal section showing occasional incomplete tabulae.

Figs 3–7. *Palaeophyllum*? *patulum* sp. nov., Clearview Limestone Member (Ballingoole Formation) at Malachi's Hill. Figs 3–4 exhibit " pseudo-colonial " form ; others may be solitary. 3. SUP 29131, ×2·5, paratype, transverse section. 4. SUP 75194b, ×2·5, holotype, longitudinal section. 5. SUP 75186b. ×3, paratype, transverse section. Note short minor septa. 6. SUP 75187a, ×2·5, paratype, longitudinal section. 7. SUP 75182b, ×3·5, paratype, transverse section of corallite surrounded by clathrodictyid stromatoporoid, *Plexodictyon*? sp.

Figs 8–10. *Palaeophyllum*? *laxum* sp. nov., uppermost part of Canomodine Limestone, Belubula River east of " Cranky Rock ". 8. SUP 75163d, ×3, holotype, transverse section. 9. SUP 43264, ×1·5, paratype, transverse section. 10. SUP 75169, ×2·5, paratype, longitudinal section.

Plate xxix

Figs 1–3. *Palaeophyllum*? *laxum* sp. nov., uppermost part of Canomodine Limestone, Belubula River east of " Cranky Rock ". 1. SUP 75163b, ×3, holotype, transverse section. 2. SUP 75168, ×3, paratype, transverse section. 3. SUP 75164, ×2·5, paratype, longitudinal section.

Figs 4–11. *Bowanophyllum pilatum* gen. et sp. nov., unnamed limestone at top of Malachi's Hill Beds, north-east of Malachi's Hill. 4. SUP 75197c, ×3, holotype, transverse section. 5. SUP 75198b, ×3, paratype, longitudinal section showing deep calice partitioned at the base by two complete tabulae. 6. SUP 75195c, ×2, paratype, longitudinal section exhibiting rejuvenescence with associated tabulae. 7. SUP 75198a, ×3, paratype, transverse section showing rejuvenescence. 8. SUP 75202b, ×8, paratype, transverse section in calical region showing trabeculae of uncertain original microstructure set in lamellar sclerenchyme. 9. SUP 75206, ×3, paratype, transverse section exhibiting spinose character of septa. 10. SUP 75200d, ×2·5, paratype, oblique longitudinal section showing rows of inclined trabeculae. 11. SUP 75200e ×2·5, paratype, transverse section.

Plate xxx

All specimens come from unnamed limestone at top of Malachi's Hill Beds, north-east of Malachi's Hill.

Fig. 1. *Bowanophyllum pilatum* gen. et sp. nov., SUP 75197a, ×8, holotype, transverse section showing solid tissue of long, rod-like trabeculae of uncertain original microstructure draped in lamellar sclerenchyme. Note elongate, light-coloured area midway between outer wall and axis which represents only open space in otherwise dense tissue.

Figs 2–4. *Bowanophyllum* sp., ×4. 2. SUP 75210b, transverse section showing weak differentiation of minor septa at rejuvenescence. 3. SUP 75208a, transverse section. 4. SUP 75208b, longitudinal section exhibiting tabularial area filled with dense septal tissue except for a single open space bounded by two tabulae.

Figs 5–11. *Rhabdelasma exigua* gen. et sp. nov. 5. SUP 75214a, ×5, paratype, transverse section exhibiting two corallites in contact. 6. SUP 75213a, ×5, paratype, transverse section. 7. SUP 75213c, ×5, paratype, transverse section. 8. SUP 75214b, ×5, paratype, transverse section showing three corallites in contact. Larger corallite situated towards top margin of figure exhibits two very tiny, possible lateral buds. 9. SUP 75212b, ×5, holotype, longitudinal section. Note small part of an associated favositid colony at top left. 10. SUP 75217b, ×5, paratype, oblique transverse section of large specimen. 11. SUP 75215b, ×10, paratype, tangential longitudinal section of curved specimen showing rhabdacanthine character of septa in peripheral stereozone breaking down into discrete spines in tabularium.

Corrigenda

Proc. Linn. Soc. N.S.W., 100 : 184, line 5, *read* Kitaygorod ; 186, *for* Major septa extend 0·5–0·6 of corallite radius, *read* Minor septa extend 0·5–0·6 of length of major septa.